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FLOW-3D®

for Coating & MEMS

Connect & Development
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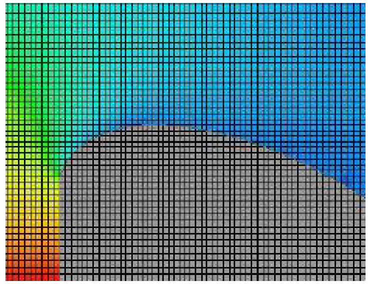
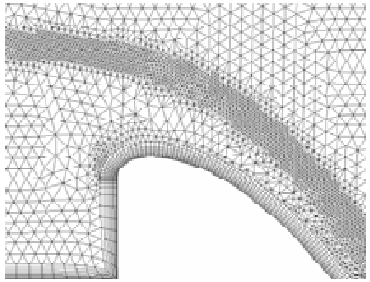
FLOW-3D® 의 장점

- ❖ 해석 모델 작성 용이
  - ◆ 경계밀착격자를 사용하지 않고 직각 격자, FAVOR 기법 사용
  - ◆ 격자 생성에 필요한 시간 및 노력 최소화
  - ◆ 수위경계조건(시간에 따라 변화가능) 제공
- ❖ 해의 정확성 및 신속성
  - ◆ 자유수면 해석의 정확성
    - VOF 방법 최초 적용 (30년간 개발, 다양한 VOF 방법 제공)
  - ◆ One Fluid Model
    - 공기의 유동은 해석하지 않음 → 계산속도 향상
    - 공기로의 운동량 확산이 없어 해의 정확성 향상
  - ◆ 지형 및 구조물 영역은 계산시 자동 제외 (속도향상)
  - ◆ 해의 발산시 자동복구 기능 (시간증가분 감소후 자동 재해석)
  - ◆ Mentor Tip 제공으로 해석의 신뢰성 향상



FLOW-3D®



타 CFD S/W

FLOW-3D® Vs. FLUENT Vs. CFX

	FLOW-3D®	FLUENT	CFX
수치해석방법	**Finite Volume Approach**	Finite Volume Technique	Finite Volume Technique
Mesh Type	**Rectangular Grid Technique**	Unstructured Mesh	Unstructured Mesh
Geometry 형성	**Built-in Obstacle Modeler CAD input import**	Built-in Obstacle Modeler CAD input import	Built-in Modeler CAD input import
해석영역 Gridding	**Rectangular Mesh와 Obstacle과의 interface가 FAVOR 기법에 의해 유동장 및 비유동장에 Mesh 형성 (obstacle이 mesh영역에 존재함으로써 grid 자동생성**	Obstacle 정의에 따라 grid modeler를 사용하여 grid생성 (mesh type에 따라 user가 gambit에서 grid를 작성함)	Finite Element Technique
응용성	**General All in One Model**	General Model (Newtonian, Non-Newtonian, Free Surface 문제 등에 따라 모듈분리)	Multiphase, Radiation, Combustion, Free Surface 등 Module 분리
계산속도	**빠른 Preprocessing을 통한 Setup**	Grid 생성에 상당기간 소요	
Free Surface	**매우 정확 (VOF technique)**	VOF를 사용하지만 경계조건 적용 방법이 달라 정확한 VOF가 아님	VOF를 사용하지만 경계조건 적용 방법이 달라 정확한 VOF가 아님
Chemical Reaction	**Passive Reaction**	Generalized Reaction	Generalized Reaction

FLOW-3D® 사용자

❖ 해외 업체

- GM, Ford, Fiat, Renault, Honda, Toyota, Hitachi, Volvo, VAW Aluminum AG, ALCAN(Aluminum Canada), Alcoa Technical Center, Alumax, Buhler AG, Achen(Institut fur Verfahrens Technik), 등 세계 550여 업체

❖ 국내 업체 (판매)

- 현대-기아자동차, 삼성종합기술원, 삼성모바일디스플레이, LG전자, LG생산기술원, POSCO, Liquid-metal, KIST, 현대건설, 한국수자원공사, 한국농어촌공사 등
- 서울대, 고려대, 연세대, 서울시립대, 부산대, 인하대, 포항공대, 국민대, 충북대, 성균관대, 대불대, 강원대, 한서대, 한양대, 한국기술교육대, 동의공업대 등

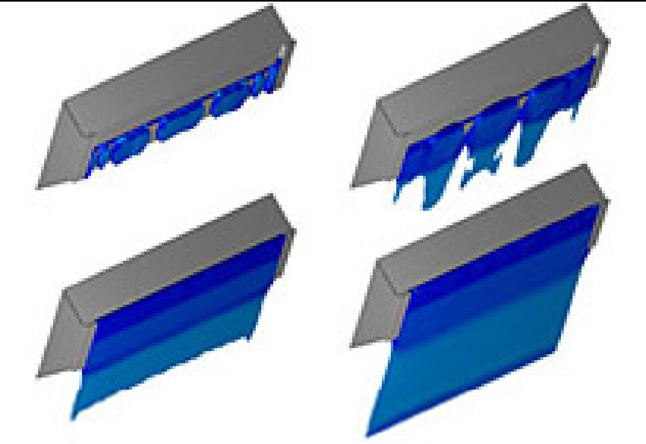
❖ 국내 업체 (용역)

- 한국수자원공사, 현대-기아자동차 연구소, KIST, 삼성종합기술원, 삼성전자, LG전자, LG생산기술원, 포항제철, 신창전기, 한국전력공사, 한국 원자력연구소, 이수금속, 만도기계, 현대중공업, 조선내화, 포스코개발 등

FLOW-3D® 해석사례

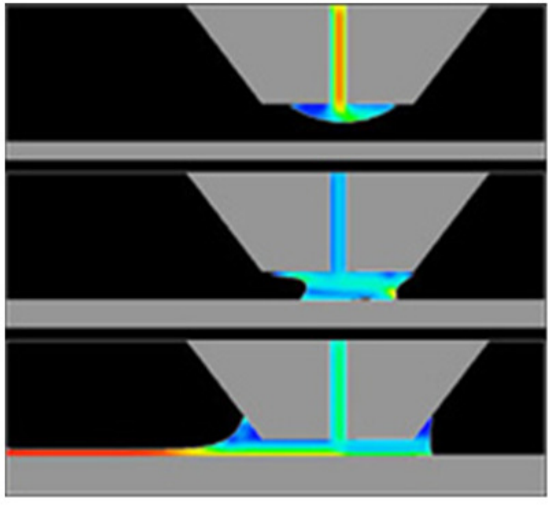
1. Coating

1. Slot Coating ; Examples



Single slot time series, 120-micron layer

Two-Layer Slot Coating



Time series of a Start-up Slot Coating

1. Slot Coating ; Examples

➤ Single-Layer Slot Coating with Elastic-Plastic Fluids

Vacuum=300 Pa

Newtonian Fluid

Contact line locates farther upstream & is stable

- Viscosity = 29*cp*, Density = 1.2*g/cm*^{3}, Surface Tension = 61*dynes/cm*, Static contact angle = 30 °

Elastic-Plastic Fluid

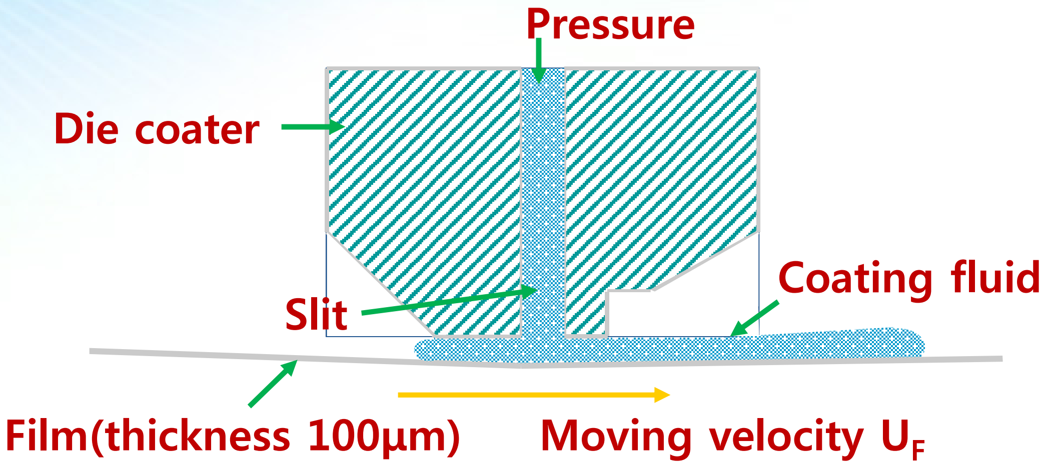
Contact line locates downstream from slot and is susceptible to air entrainment

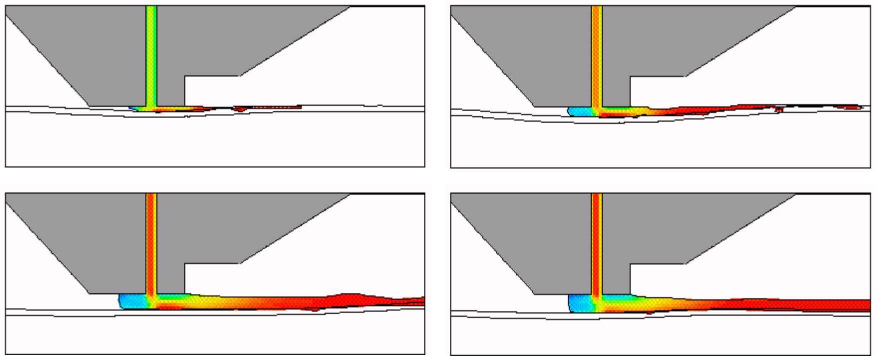
Same properties as Newtonian case,

except: Shear modulus (G) = 100*Pa*, Yield stress (Y) = 100*Pa*

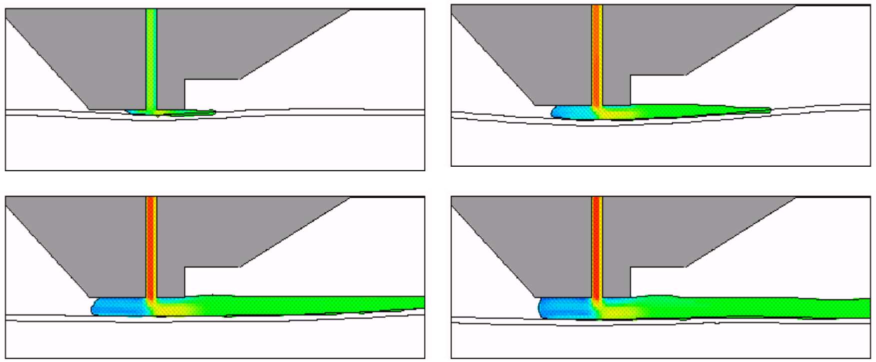
1. Slot Coating ; Examples

➢ **Coating Analysis coupled with DYNA3D**





Animation (U_F=200cm/s) CO8



Animation (U_F=100cm/s) CO9

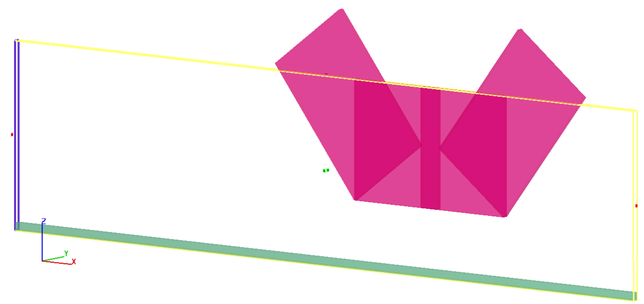
1. Slot Coating ; Model

Physics Model

- Gravity
- Moving and deforming objects
- Surface Tension
- Viscosity & Turbulence

Boundary Condition

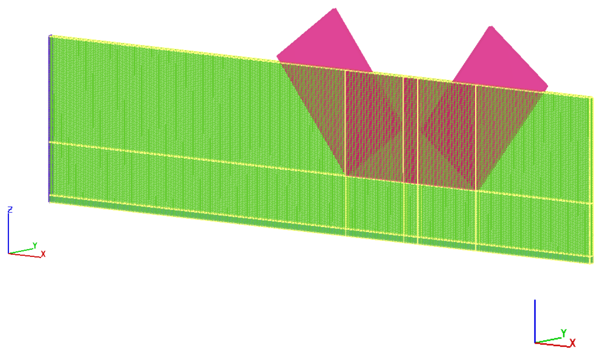
- X-min : continuative
- X-max : pressure
- Z-max : velocity

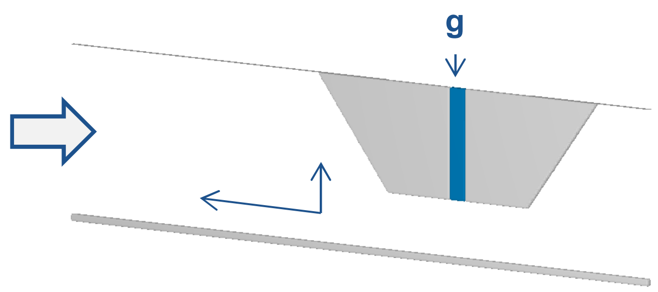


Meshing & Geometry

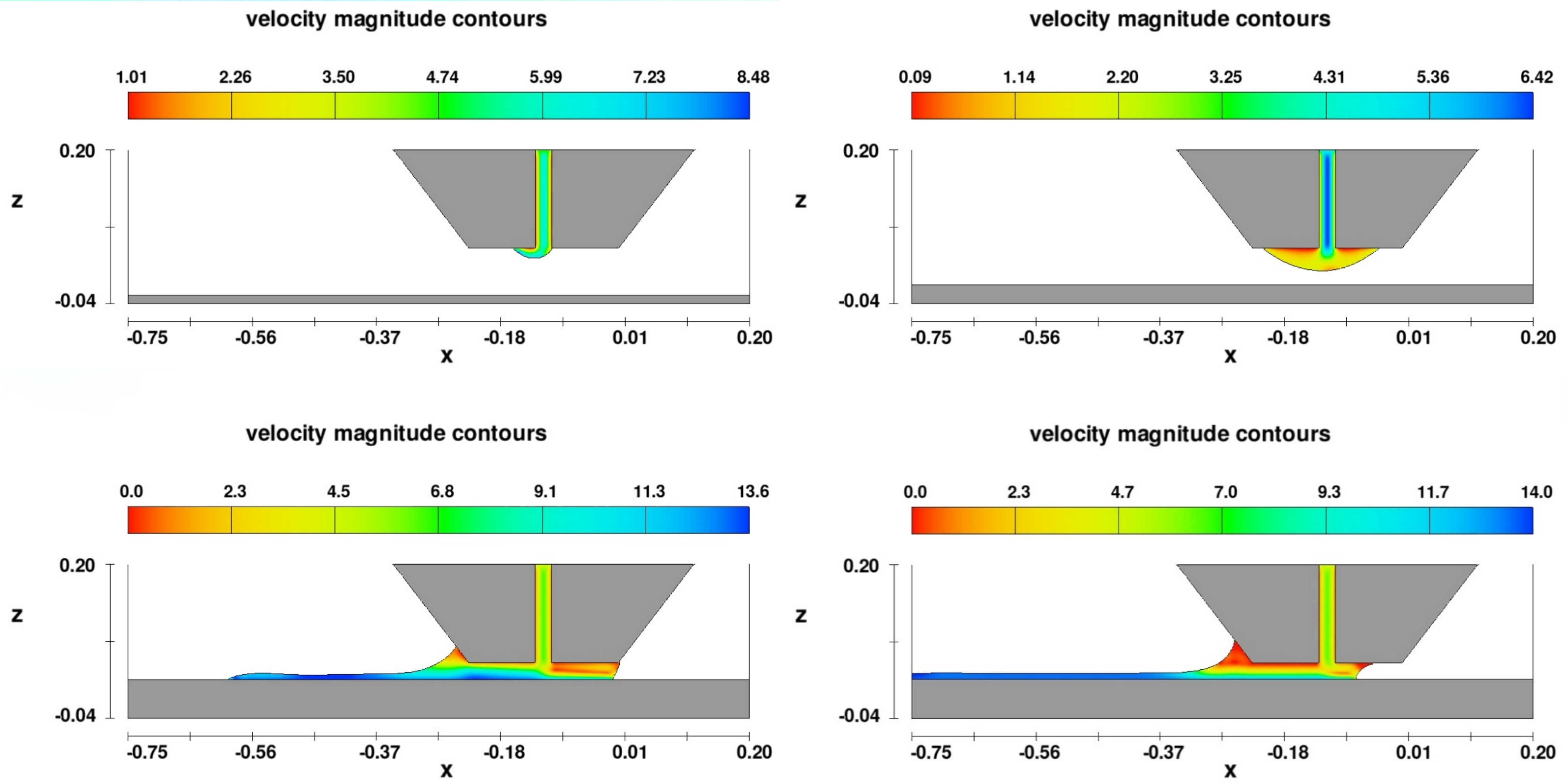
- Cells : 107,160ea
- Used 3 solid, 1hole

Favorized Component

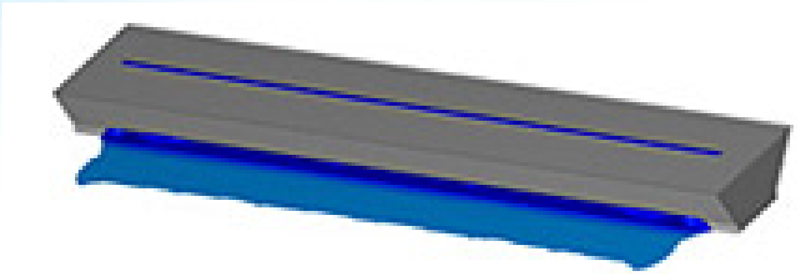




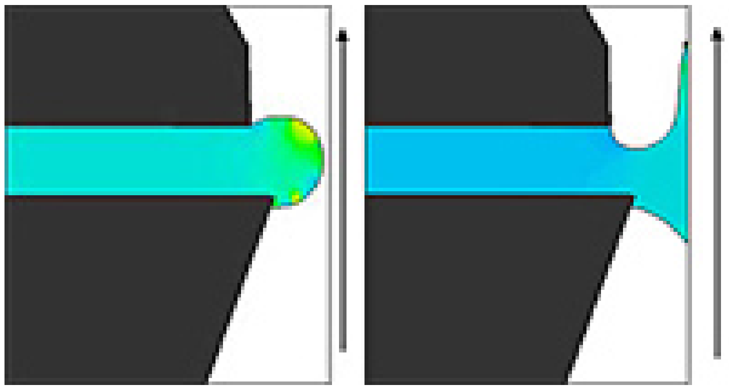
1. Slot Coating ; Results



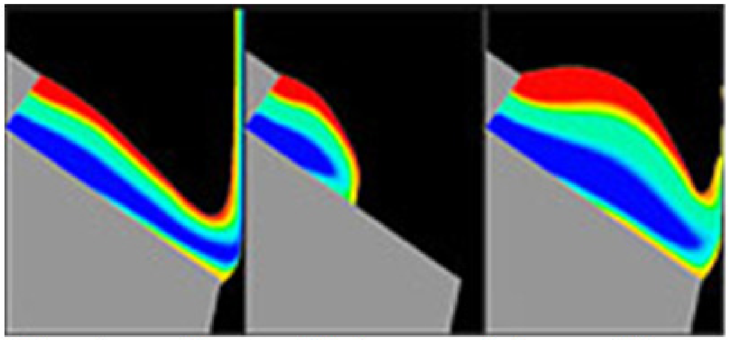
2. Slide Coating ; Examples



Start-up of slide coating process, applying coating that is 82 micron thick.

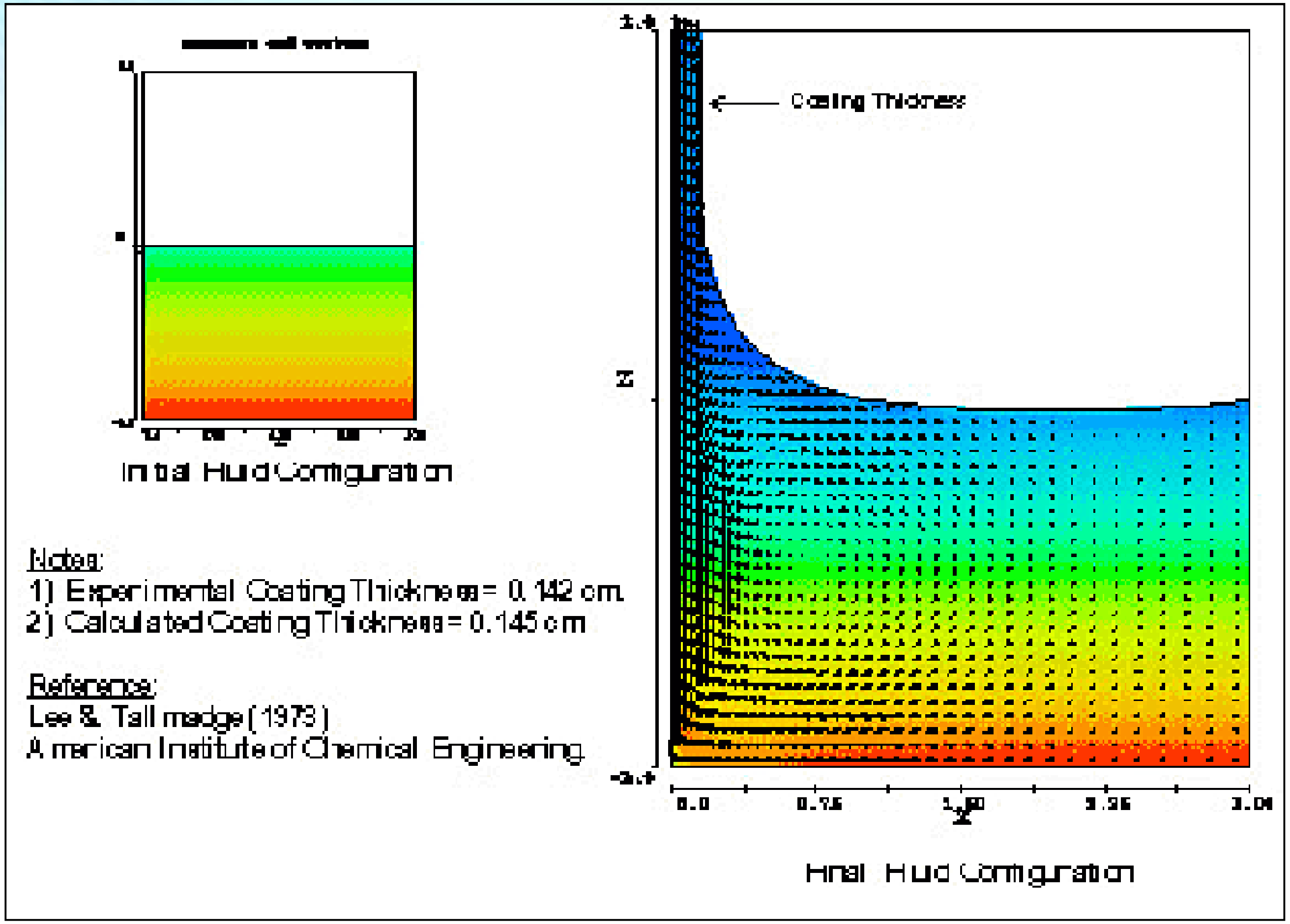


Startup of a slide coating



Startup of a multi-layer slide coating

3. Dip Coating ; Examples



3. Dip Coating ; Model

Physics Model

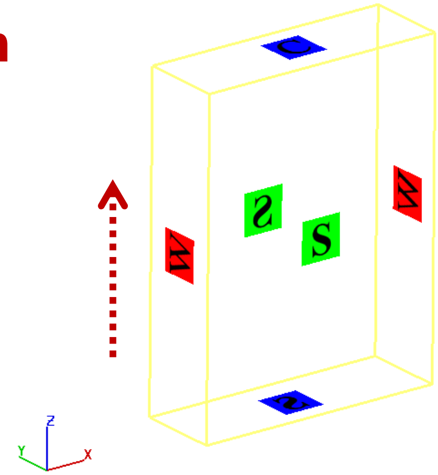
- Gravity
- Surface Tension
- Viscosity & Turbulence

Meshing & Geometry

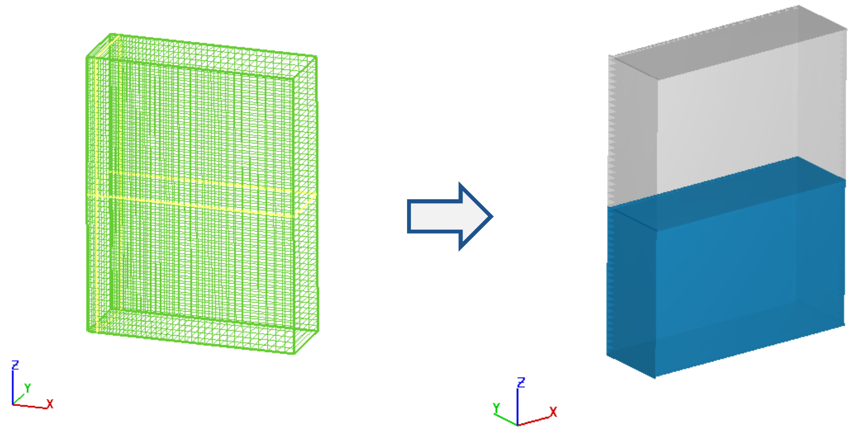
- Cells : 2,000ea
- No Component Used
- Define the fluid area
  without solid Component

Boundary Condition

- X-min : wall
- V_z = 3.31cm/sec

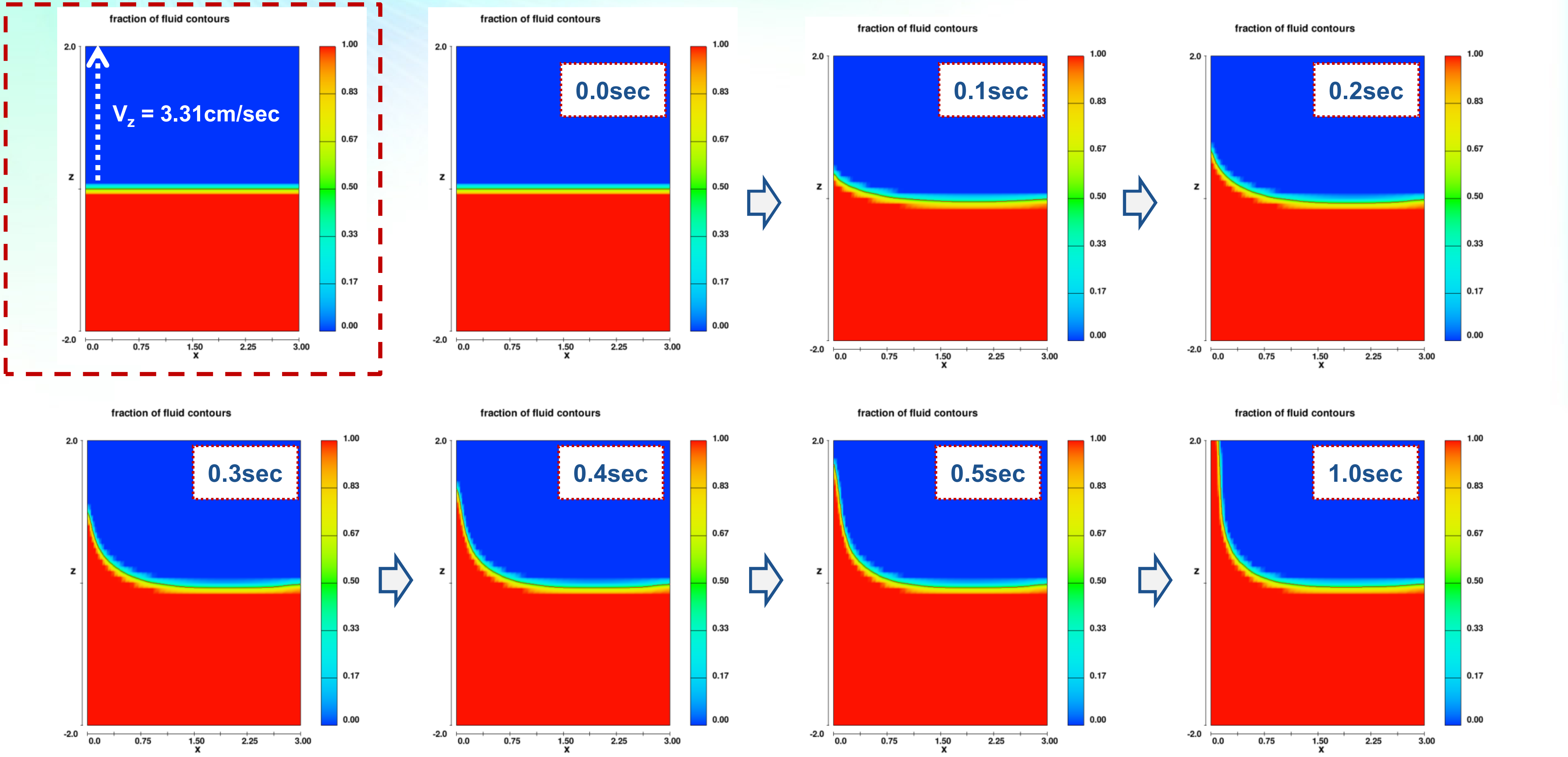


Favorized Component

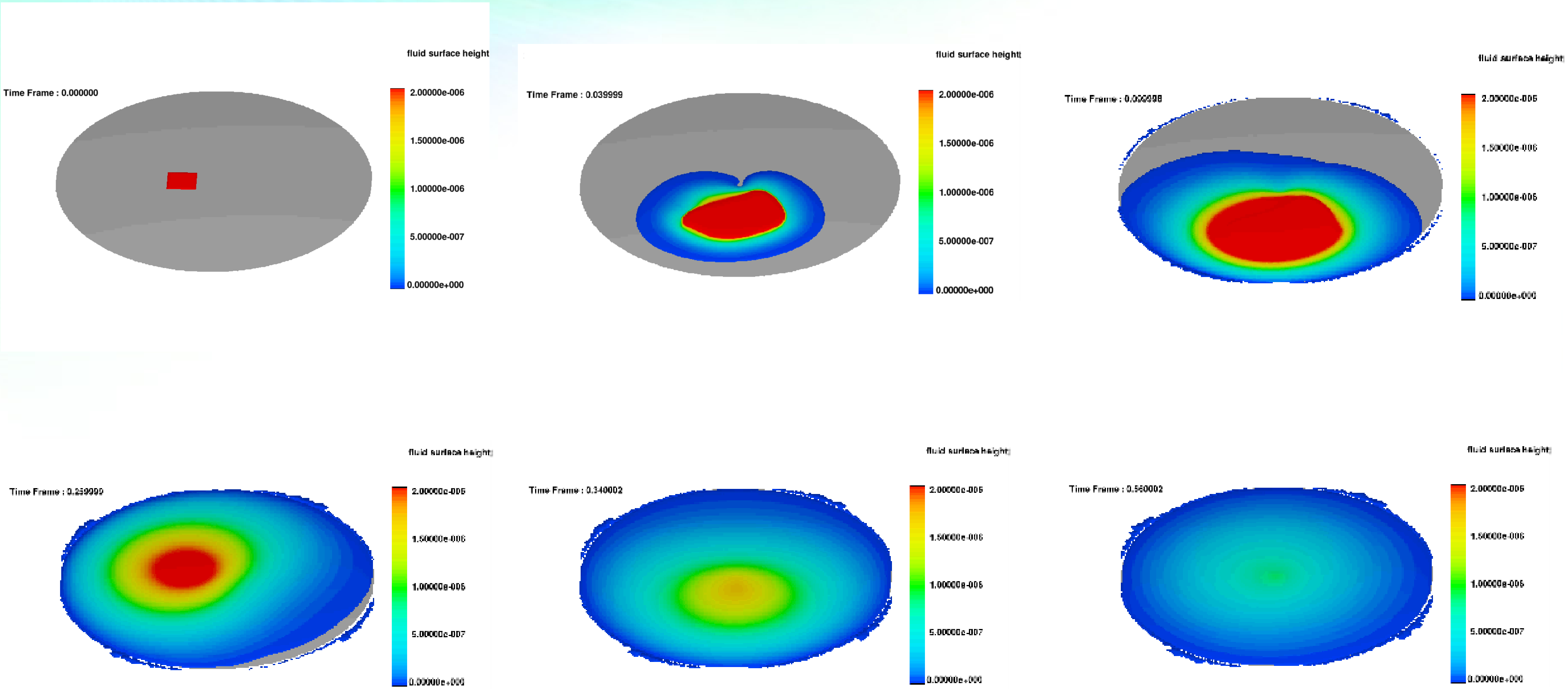


3. Dip Coating ; Results

Fraction of fluid



4. Spin Coating ; Example



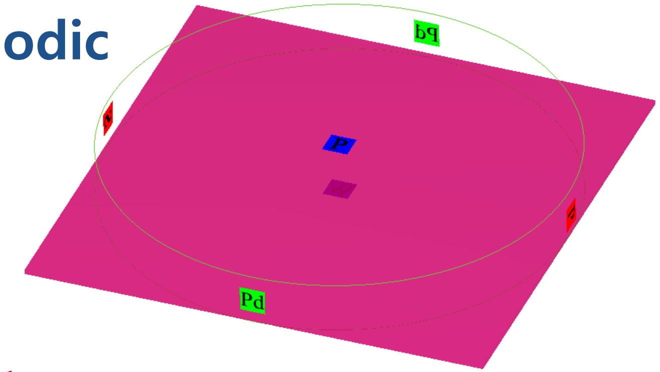
4. Spin Coating ; Model

Physics Model

- Gravity
- Shallow water
- Surface Tension
- Viscosity & Turbulence

Boundary Condition

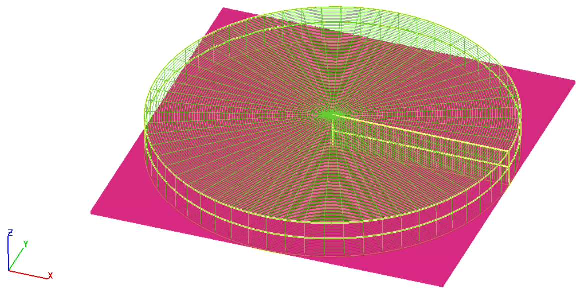
- X-max : pressure
- Y-min / max : periodic
- Z-max : pressure

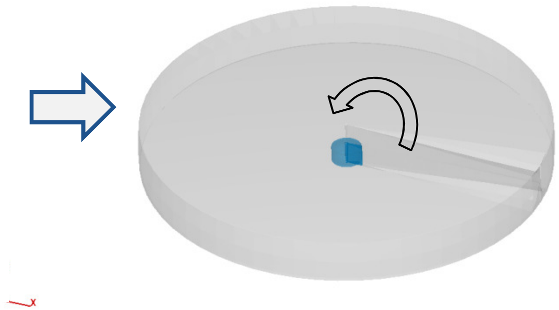


Meshing & Geometry

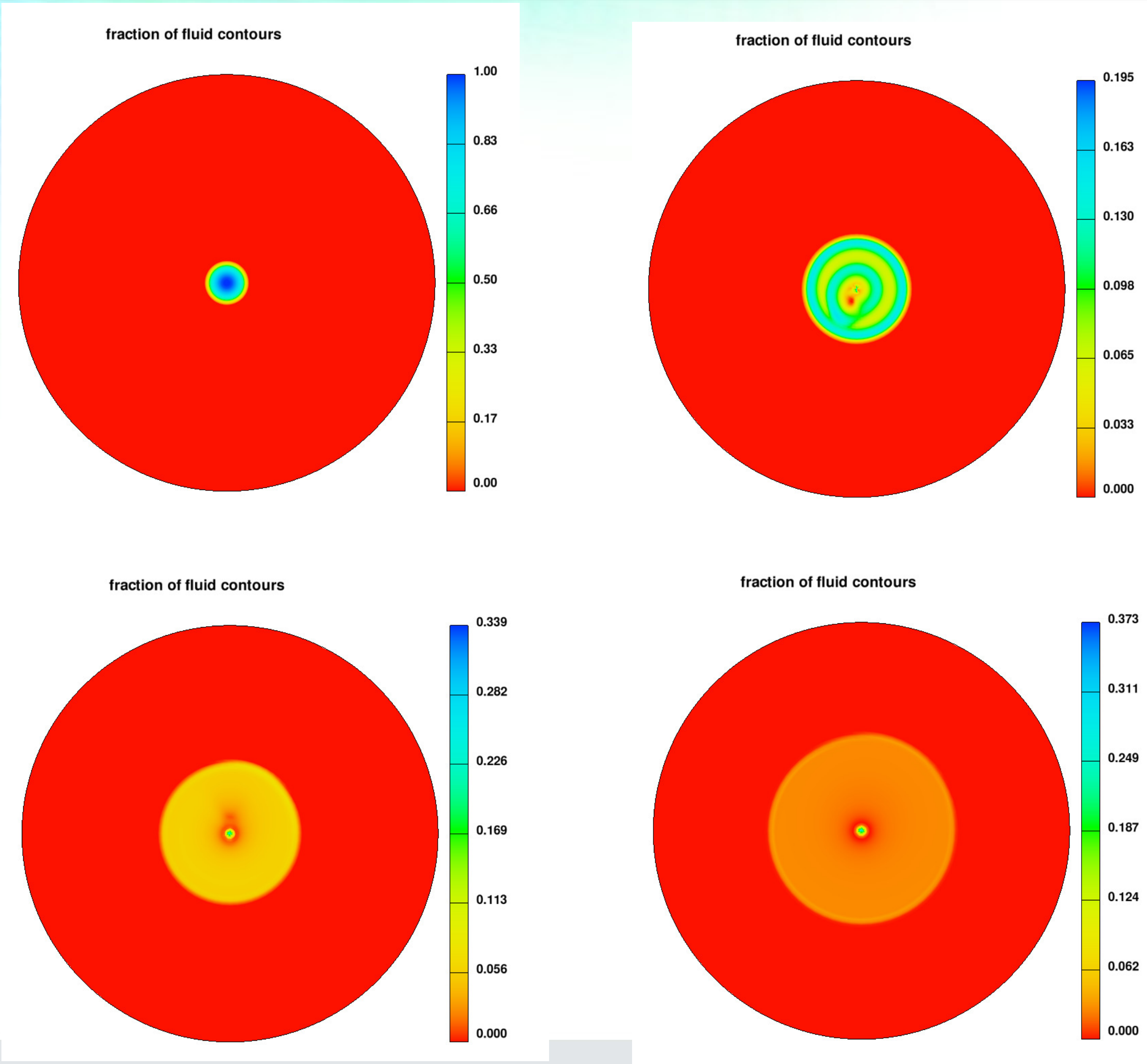
- Cells : 9,000ea
- Used cylindrical mesh

Favorized Component





4. Spin Coating ; Results



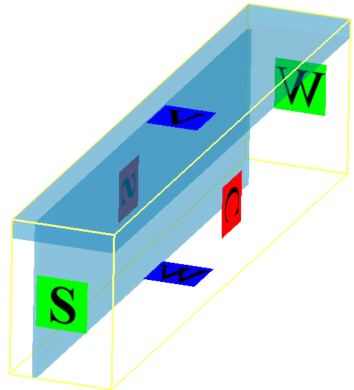
5. Curtain Coating ; Model

Physics Model

- Gravity
- Surface Tension
- Viscosity & Turbulence

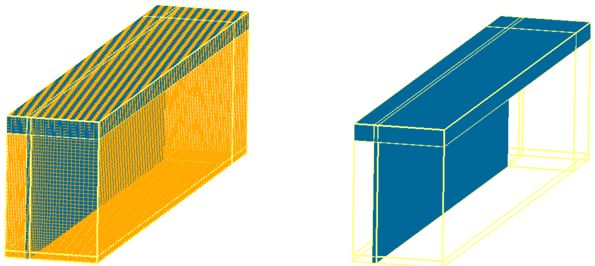
Boundary Condition

- Top : velocity
- X-max : Continuative

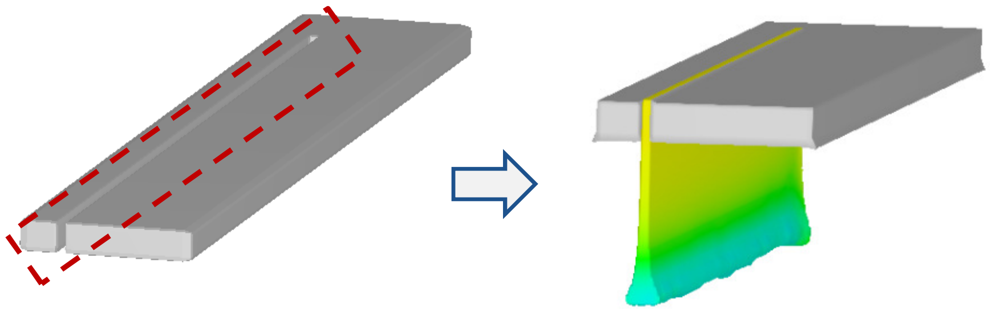


Meshing & Geometry

- Cells : 330,000ea
- Used 1 solid, 1hole

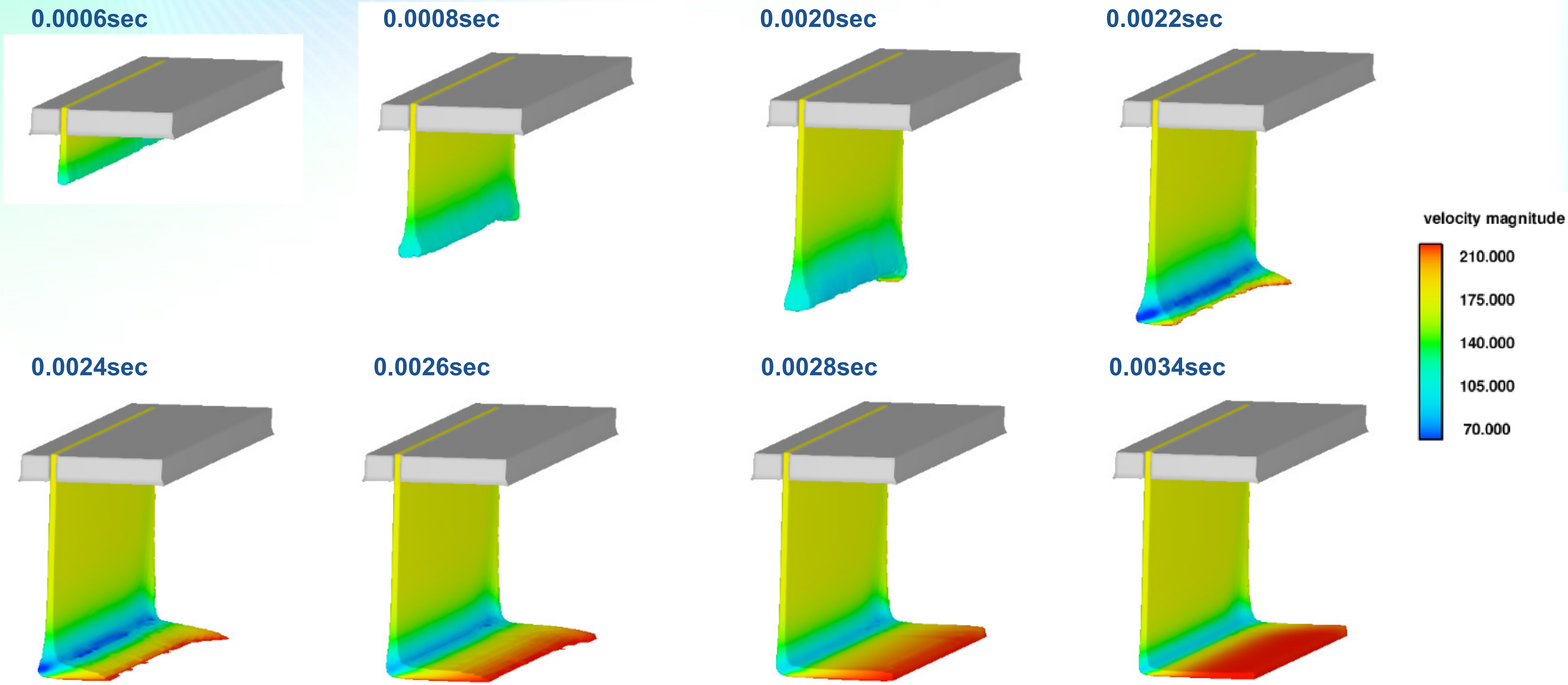


Favorized Component



5. Curtain Coating ; Results

Velocity of fluid



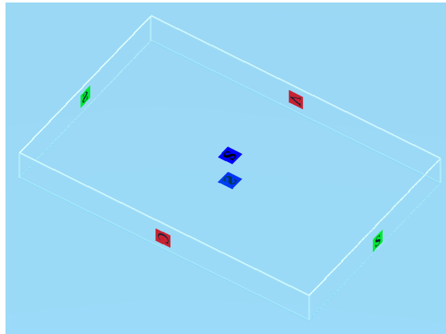
6. Roll Coating ; Model

Physics Model

- Bubble and phase change
- Moving and deforming objects
- Surface Tension
- Viscosity & Turbulence

Boundary Condition

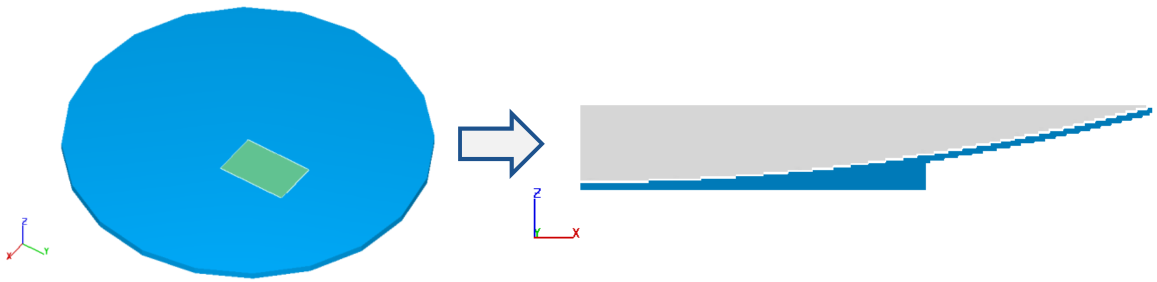
- X-min : continuative
- X-max : velocity



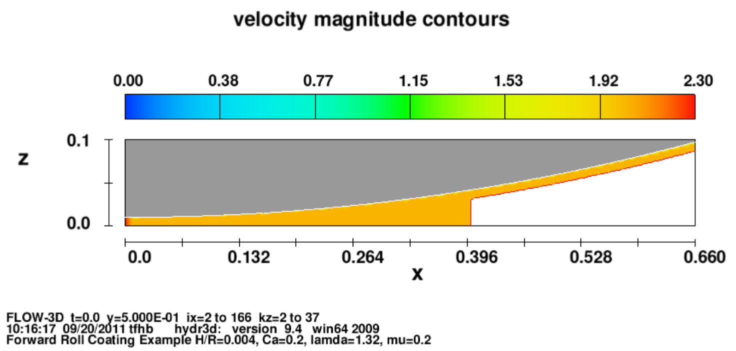
Meshing & Geometry

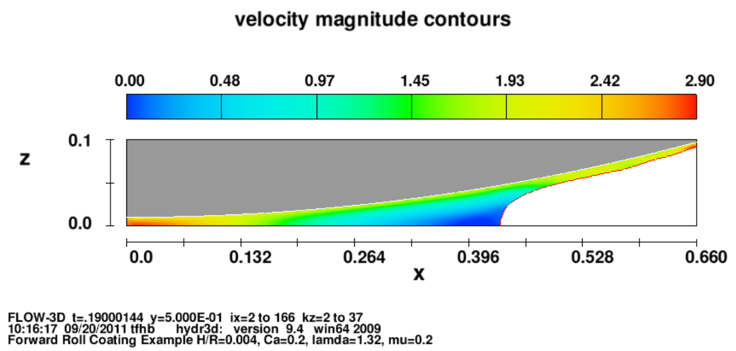
- Cells : 5,775ea
- Rotate and translate
  for component

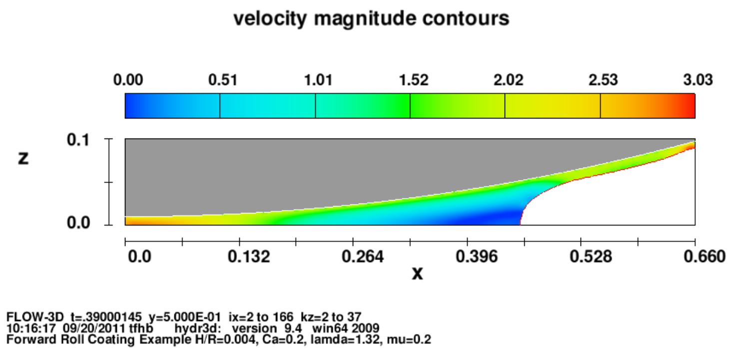
Favorized Component

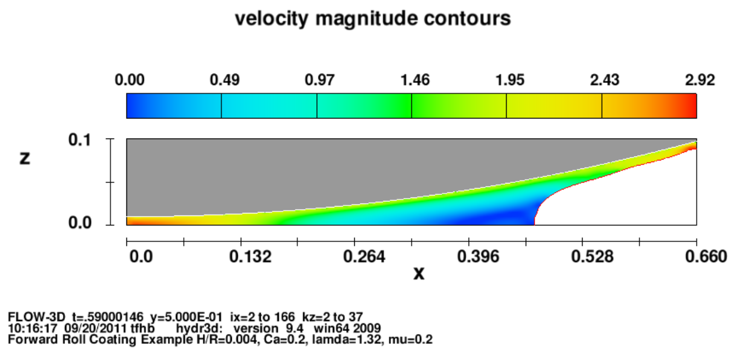


6. Roll Coating ; Results









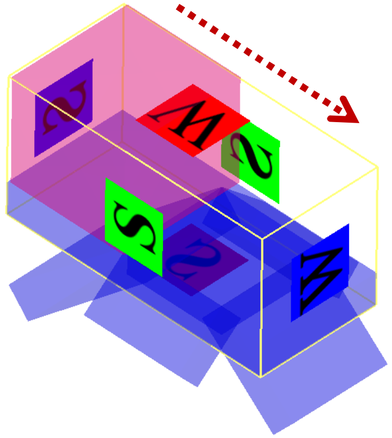
7. Gravure Printing ; Model

Physics Model

- Bubble and phase change
- Moving and deforming objects
- Surface Tension
- Viscosity & Turbulence

GMO Condition

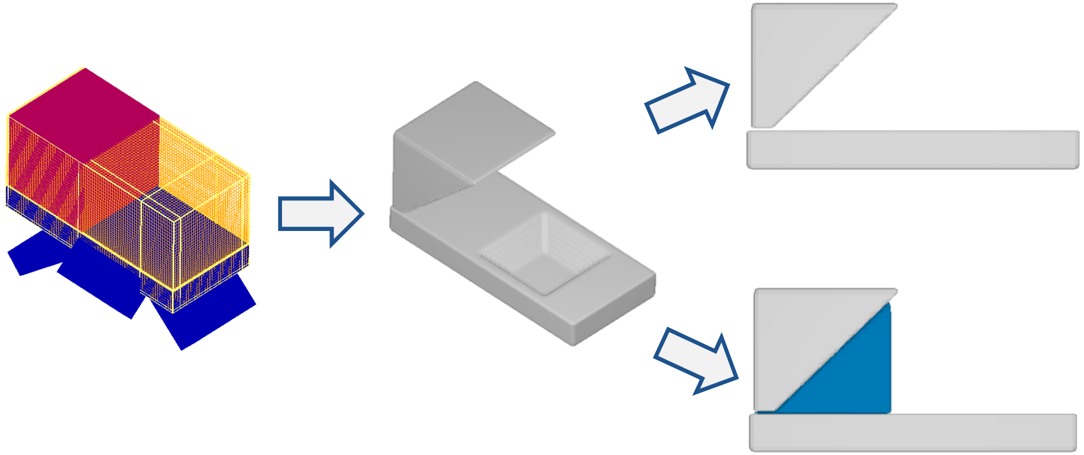
- Prescribe Motion
- V_z = -120um/sec



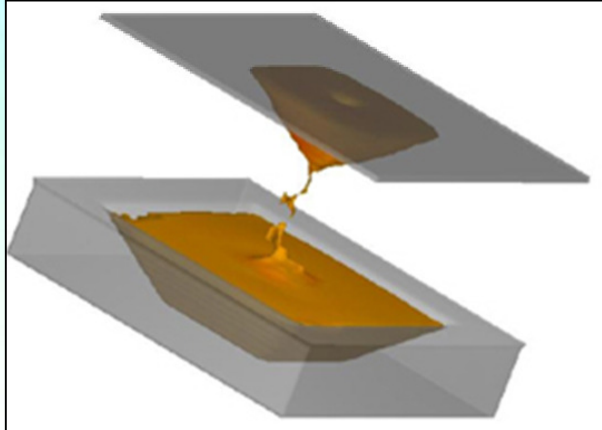
Meshing & Geometry

- Cells : 101,080ea
- No Component Used
- Define the fluid area without solid Component

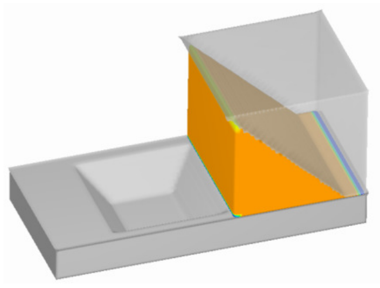
Favorized Component



7. Gravure Printing ; Results



Transfer of liquid from an individula gravure cell(bottom) onto the substrate



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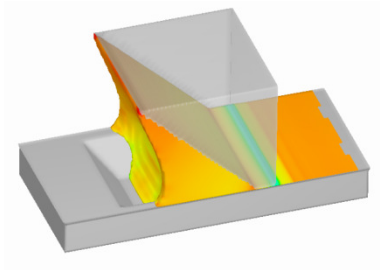

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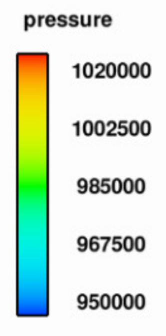

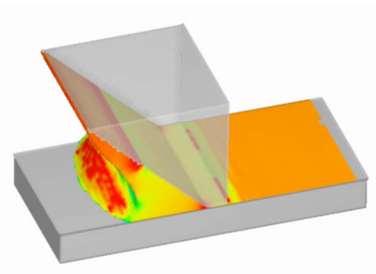

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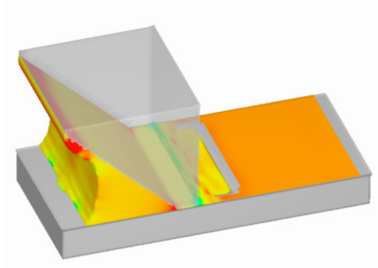

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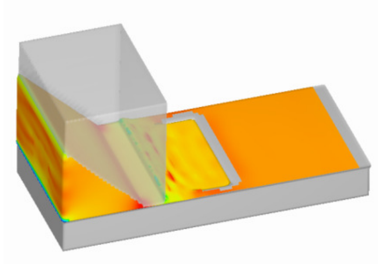

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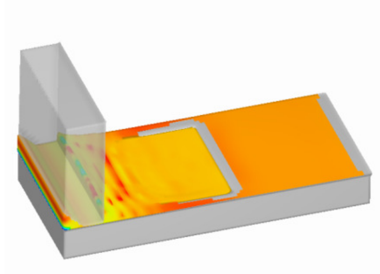

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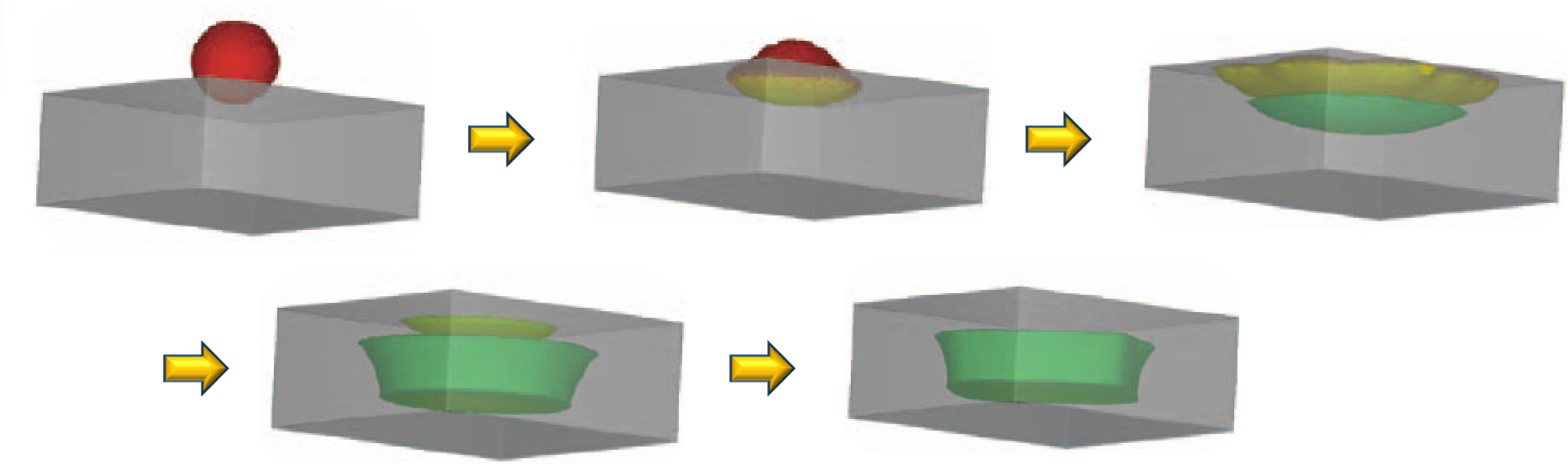
* Porous Media Model

- Distinct Saturation Front or Varying Saturation
- Complex Geometries with Varying Porosity, Permeability and Wettability
- Heat Transfer between Fluid and Solids
- Anisotropic Properties
- Hysteresis-Wettability Varies with Saturation

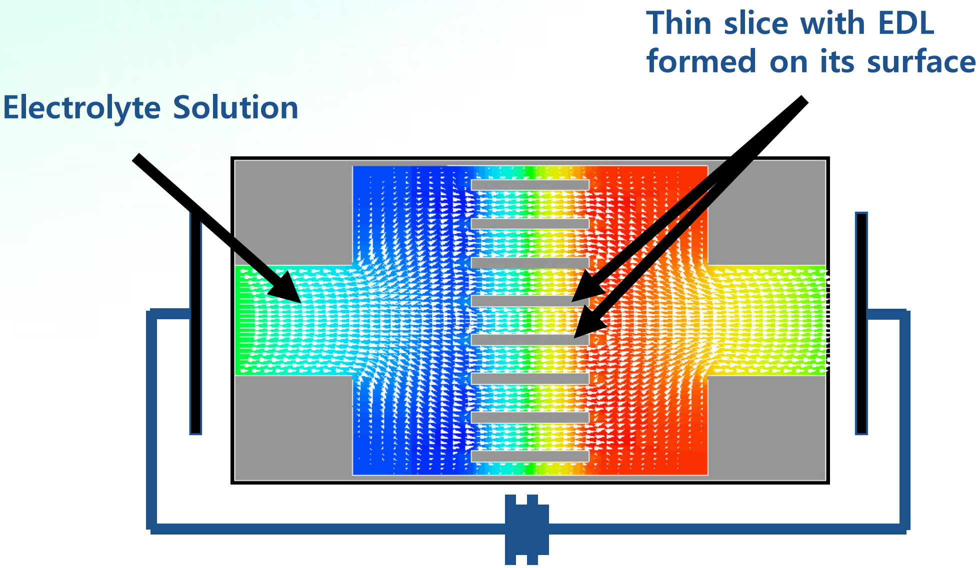


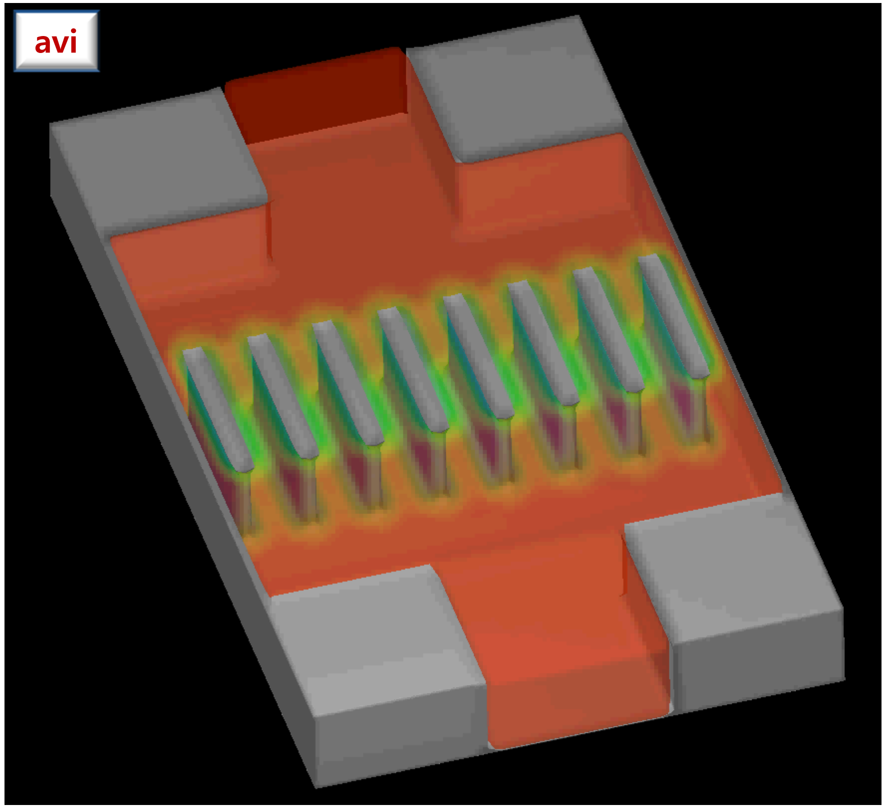
FLOW-3D® 해석사례

2. MEMS

MEMS

- By creating a series of deep slots in a microchannel, and then applying a potential across the channel, fluid flow can be controlled. By adjusting the applied potential, the flow rate can be controlled.





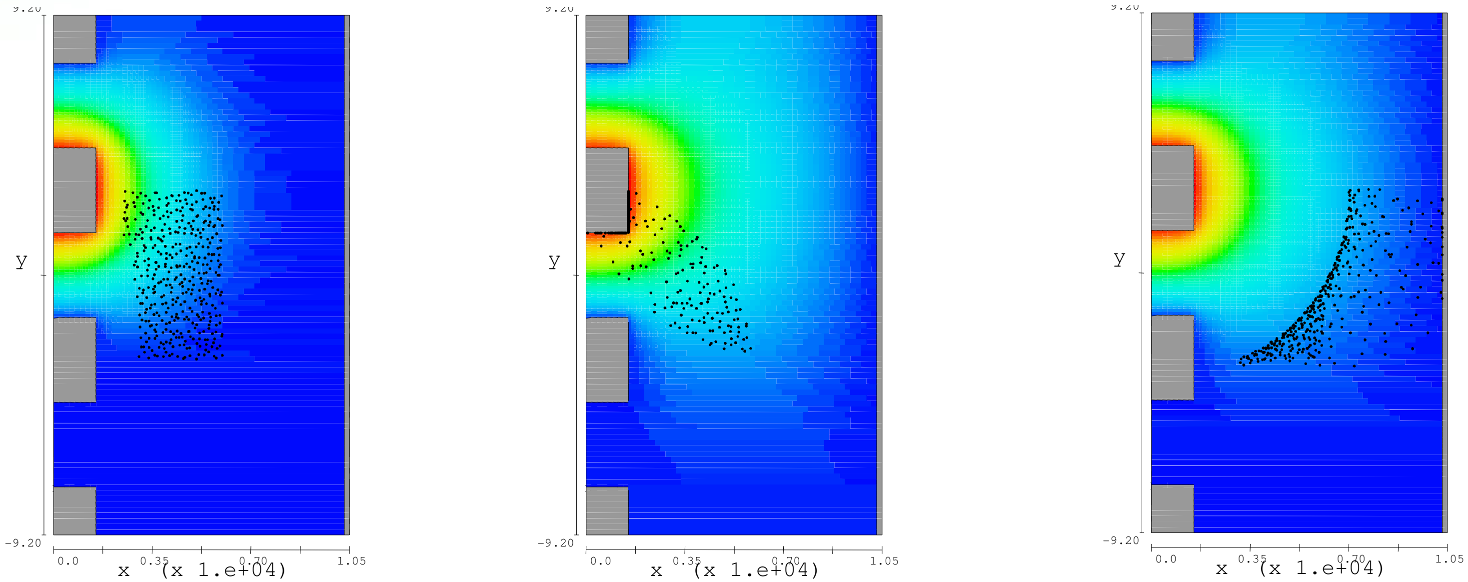
Applied Electric Potential

MEMS

- Dielectric Forces on Mass Particles
- Mass particles can be dielectric materials. The force on a dielectric particle depend on the value of the particle' s dielectric constant with respect to the dielectric constant of the surrounding fluid.
- In these examples the dielectric constant of the particles is greater than (middle frame) and less than (last frame) that of the surrounding material.

Dielectric constant > ambient

Dielectric constant < ambient



Early time

Later time

MEMS

➢ **Sprayed Polymer Particles**

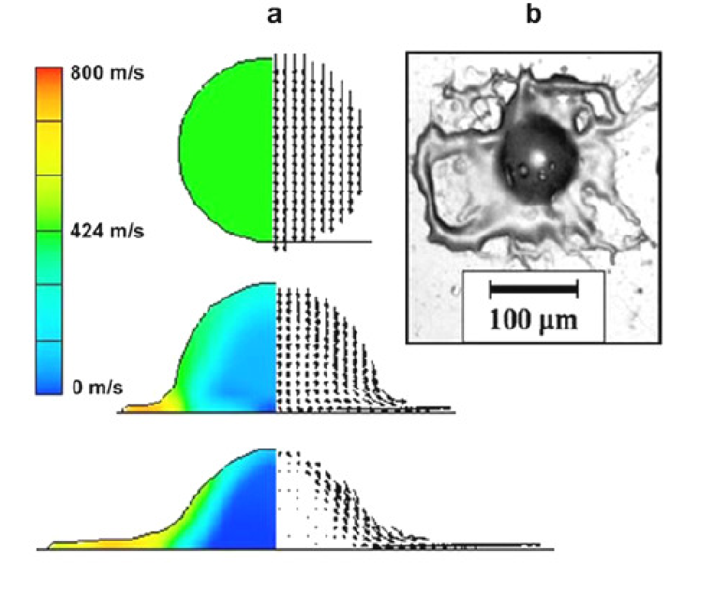


Figure 2: (a) Velocity field within a spreading 90 µm diameter particle; (Left): velocity magnitude, (Right): velocity vectors, (b) example Nylon 11 splat deposited via swipe test onto a room temperature glass slide.

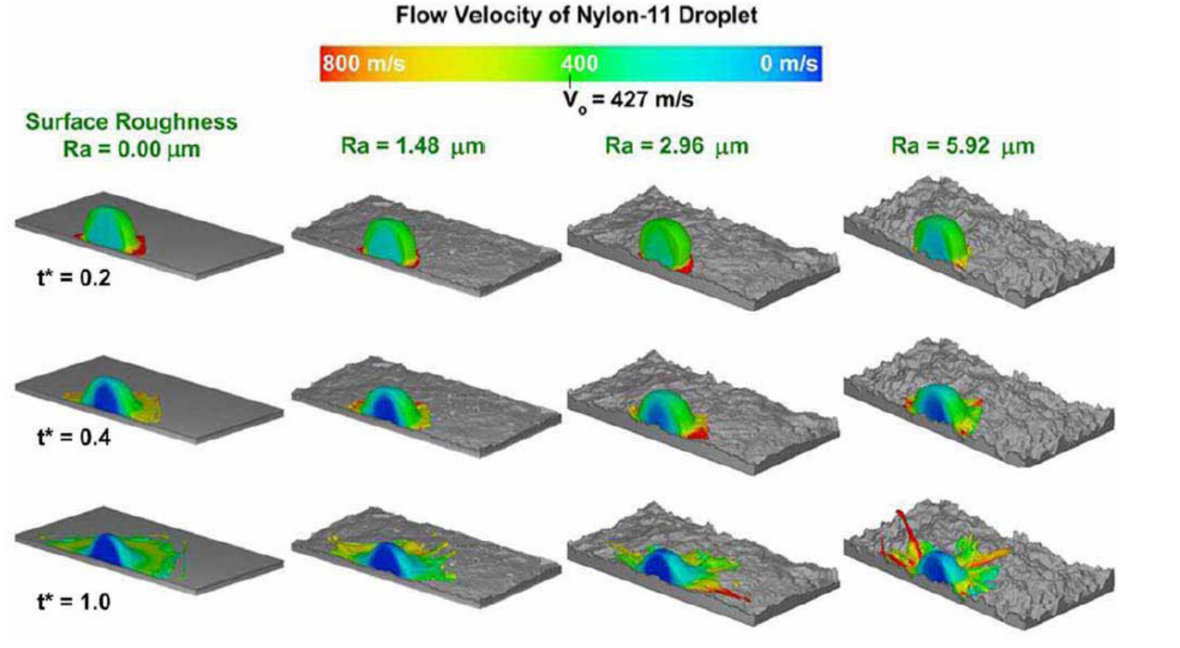


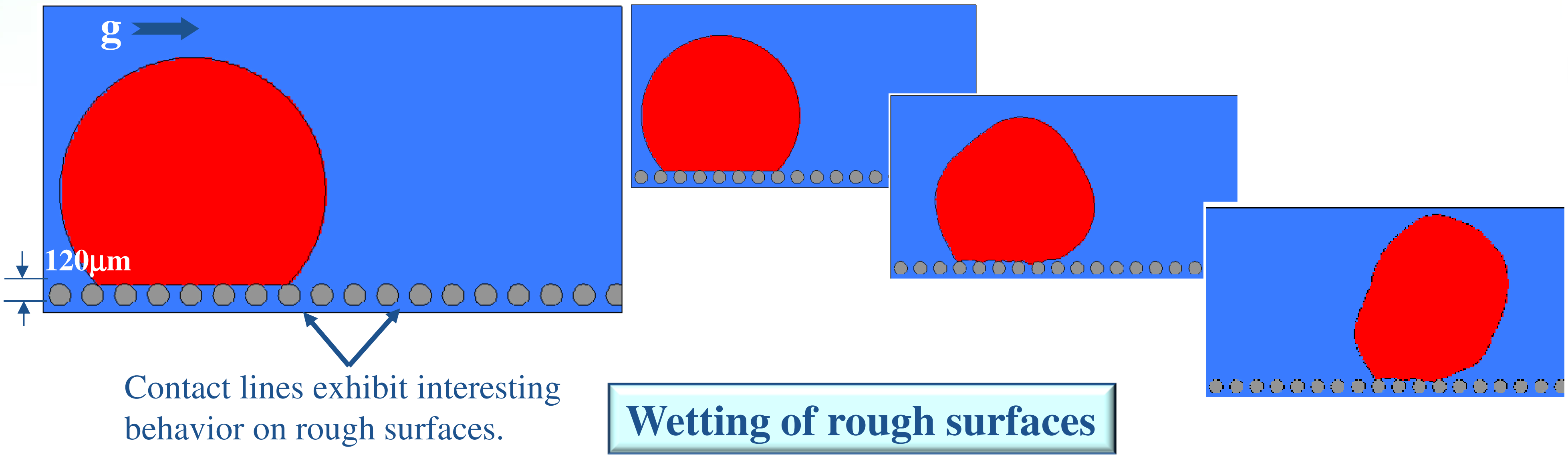
Figure 8: Cross-sections of predicted three-dimensional spreading splats for a 90 µm diameter Nylon-11 particle on four different surface roughnesses (dimensionless time $t^* = t/(D/v^o_{(p)})$).

International Thermal Spray Conference – ITSC-2006
Effect of Substrate Roughness on Splatting Behavior of HVOF Sprayed Polymer Particles

MEMS

Wall Adhesion

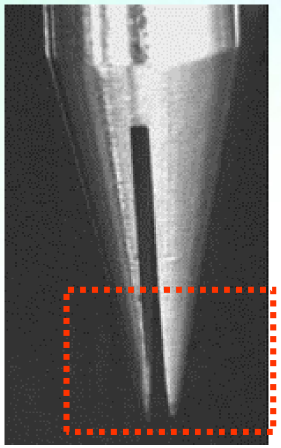
- Adhesion of liquid with solid surfaces can occur at contact lines.
- This slide demonstrates one use of surface tension and adhesion effects – that of determining the wetting (or non-wetting) properties of rough surfaces. For illustration purposes this is a 2D example.
- The cylinders have diameters approximating that of coarse hair.

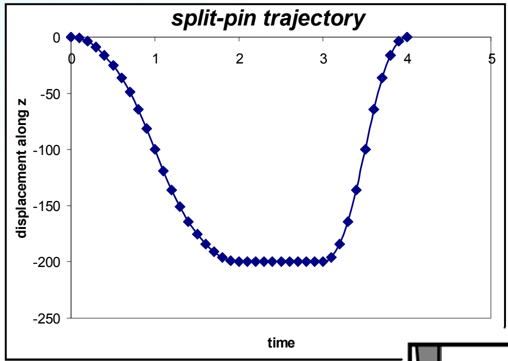


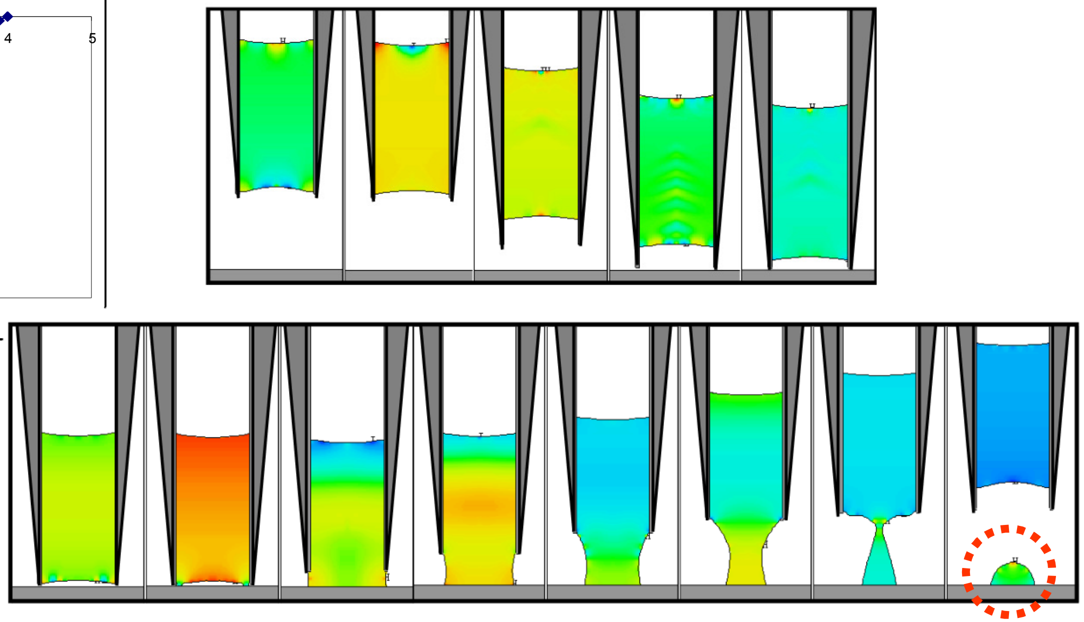
MEMS

Micro Arraying (DNA-Chip or Bio-Chip)

➢ DNA Chip 해석 :해석을 통하여 Probe와 유체간의 유동양상을 파악할 수 있다.



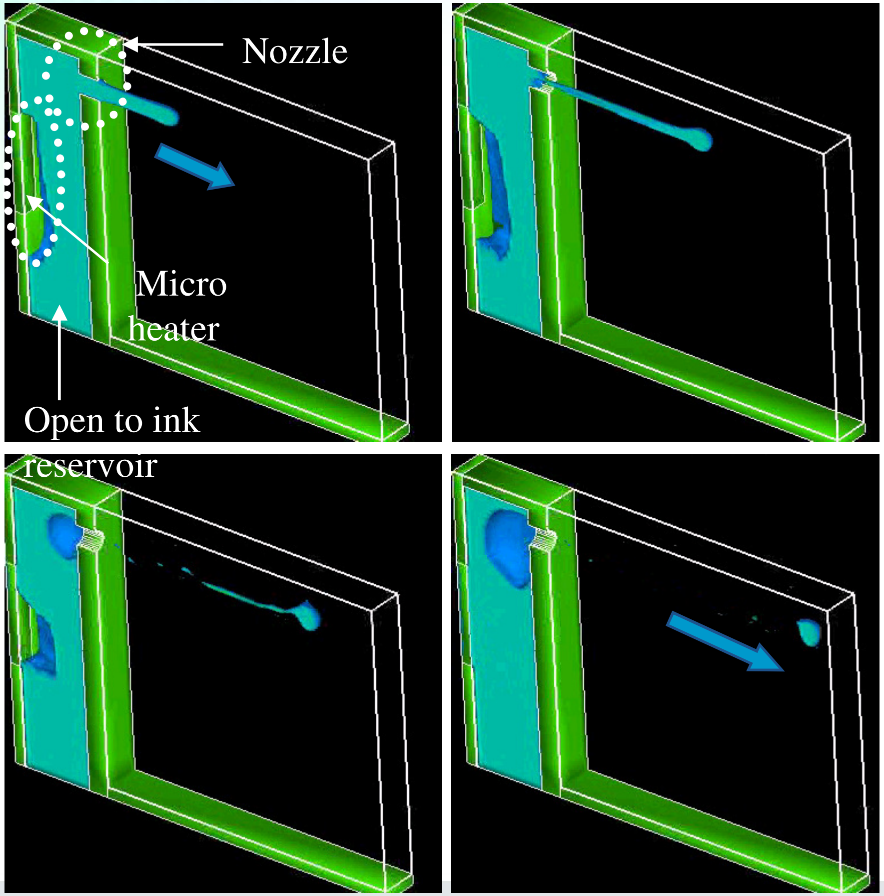


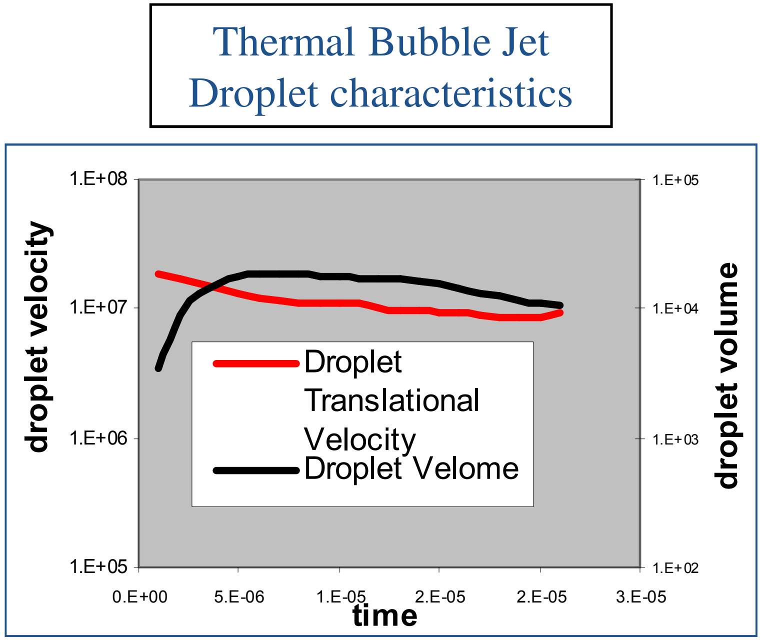


※ DNA-Chip: 유리판, nitrocellulose membrane 혹은 silicon 위에 target DNA (cDNA 또는 Oligonucleotide)를 붙인 것. 형광물질 혹은 방사선 동위 원소로 표식된 탐침(probe)과 hybridization 시켜 유전자의 발현 정도, 돌연 변이의 확인, single nucleotide polymorphism (SNP), 질병의 진단, high-throughput screening (HTS)등에 사용할 수 있다.

MEMS

- **Bubble jet solutions**
- **FLOW-3D Solver를 통한 Bubble jet의 유동양상 해석**
- **Nozzle를 통한 액적(Droplet)의 미소유속 및 유량을 파악 가능**



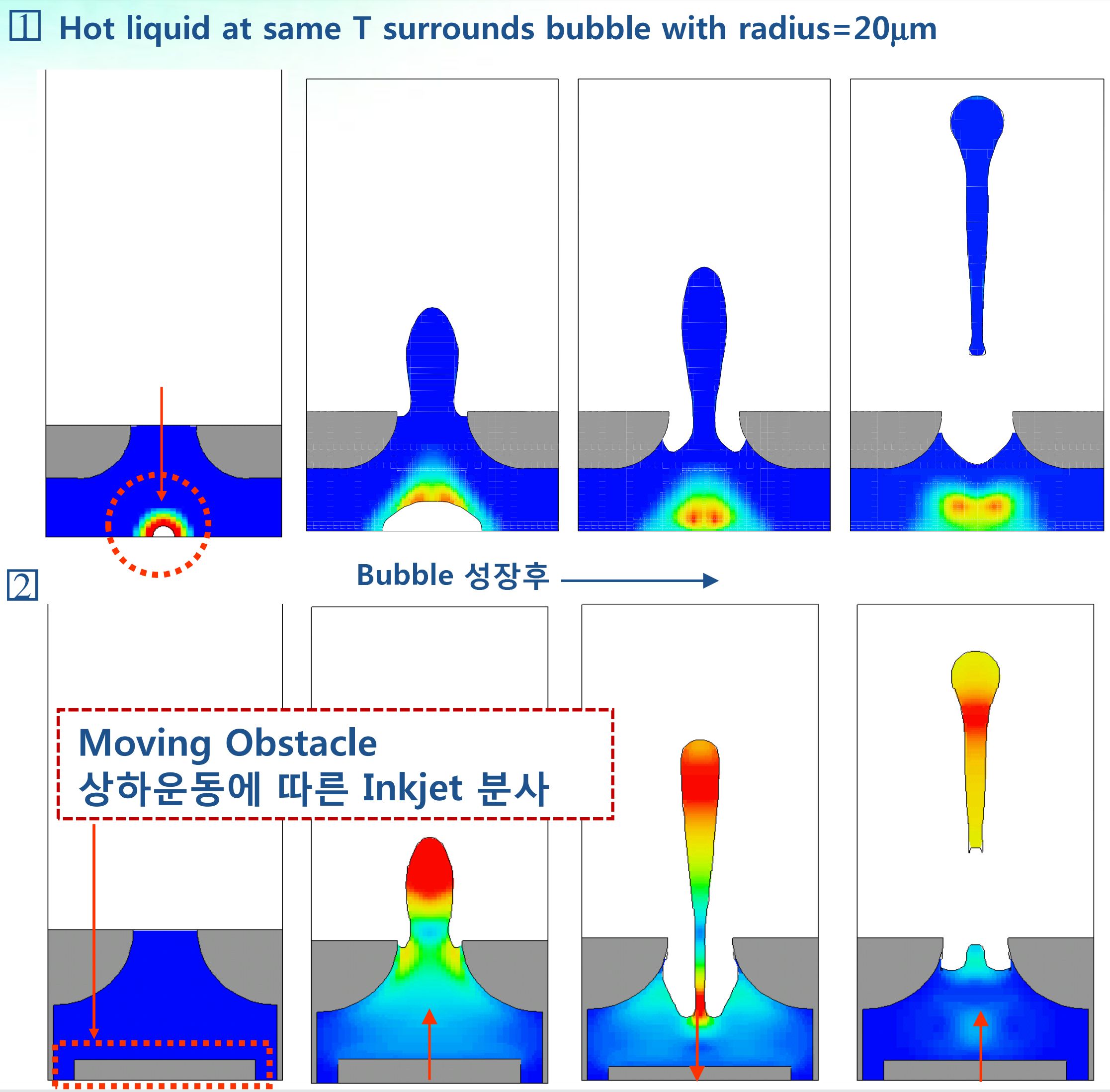


MEMS

- **Bubble jet solutions**

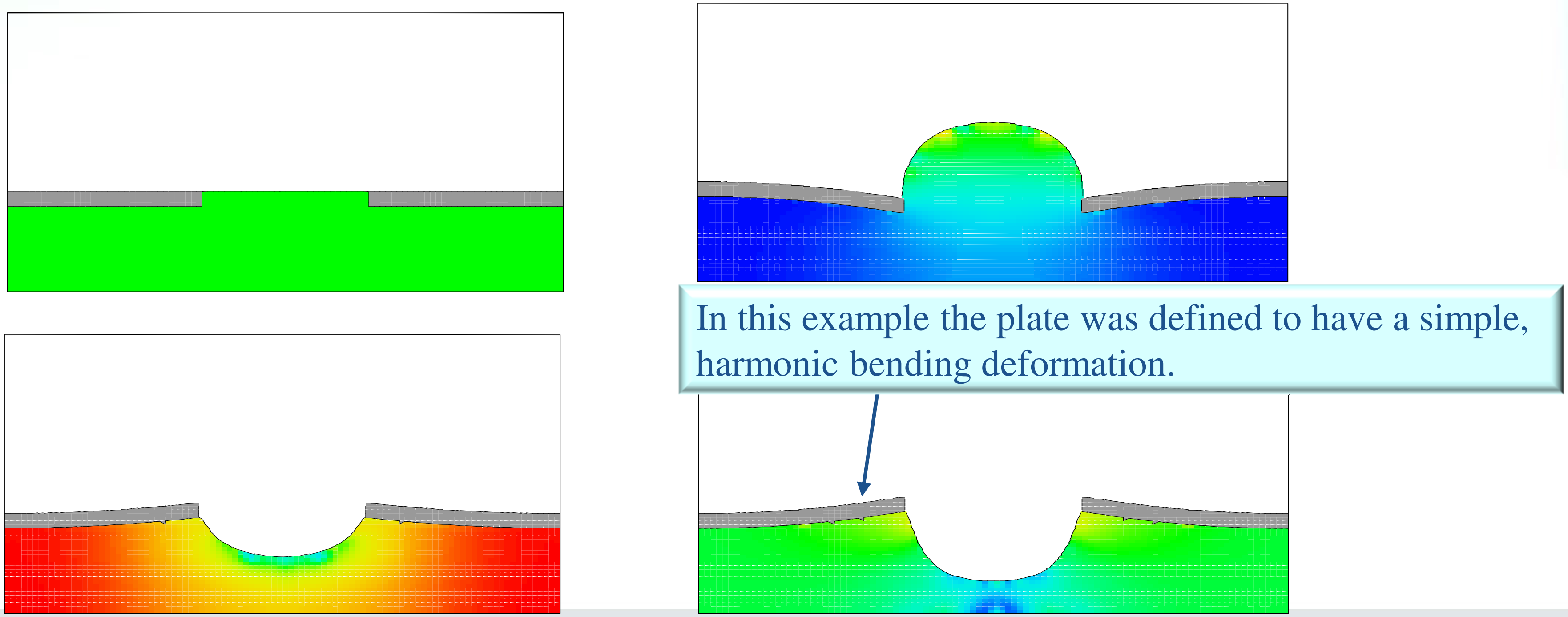
- 초기 Bubble조건이 주어진 상태에서 성장 후 붕괴되어지는 과정을 모사
- 표면온도에서의 냉각과 팽창으로 인한 Bubble의 급냉 발생
- 해석을 통해 Droplet의 분출 유동양상, 유량, 유속 등을 확인

- Moving Obstacle을 이용한 inkjet 해석
- Bubble과의 비교를 통한 액적의 분사 유동양상 확인
- 해석을 통해 Droplet의 분출 유동양상, 유량, 유속 확인



MEMS

- ❖ An additional feature available with the improved moving obstacle model is the ability to customize the velocity of each point over its surface. The customization is done through a source code routine available to users called velmov.f.
- ❖ In the simple example shown in this slide, a plate with a circular hole has been given a bending motion. The deformation is assumed to be sinusoidal. Initially the downward motion drives fluid out the opening, but before a droplet is expelled, the plate moves up and sucks the fluid back into the closed chamber.



대단히 감사합니다.

항상 고객여러분을 위해 준비되어 있습니다.

Connect & Development

주식회사 에스티아이 C&D

창조적 지식기반 전문엔지니어그룹